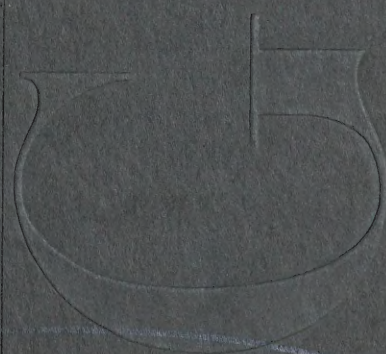


AR25

PERSPECTIVE

MAR 27 1981

File



GENERAL DYNAMICS

Perspective

This is the story of 105,000 persons, working together in over 170 locations—of men and women carefully chosen, provided with superb facilities, and given scope for imaginative and daring concepts / It is about great products—but more so of the philosophies, the capabilities, and the techniques that made the great products possible / It tells of four new ages of man—the space age, the jet age, the nuclear age and the undersea age—and of a company that served as a catalyst for all of them / It is the story of a creed: scientific excellence—with a sense of mission / It is the story of General Dynamics Corporation





Section

1

CAPABILITY FOR DEFENSE

Polaris-firing submarine USS Patrick Henry, second of her class, goes on station.

Change comes quickly nowadays. From the Wright Brothers' first flight, at 30 miles per hour, to the transonic speed of postwar military planes took 50 years. To double that speed took four years. From the first war rockets used in China to the German V-2 of World War II took 500 years—between the slow, erratic V-2 and mighty rockets capable of taking a man into space only 15 years passed. The first practical submersible was able to stay under the surface for 10 minutes; 50 years later the submarine could still run submerged for only a few hours. The leap to giant nuclear submarines capable of remaining submerged almost indefinitely at high speed took four years.

To be successful in such a world requires three abilities:

To adapt to change as it occurs;
To anticipate change and be ready before it occurs;
And to create the change, to pull the future into today.

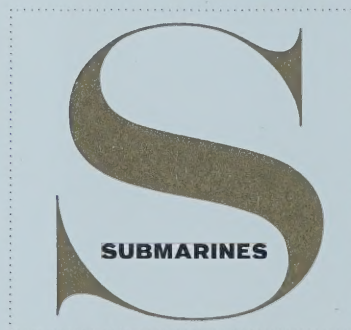
In all of these, General Dynamics excels. In one decade General Dynamics has grown from a small, specialized submarine-building yard in Connecticut to a vast and unique industrial complex. It is still a submarine builder. It is also an aircraft company; an electronics company; a research company; a space company; a nuclear company. It is a coal miner, a machinery maker, a producer of gases and building materials.

Its laboratories and plants have paced the scientific explosion. Almost 90% of the current products of General Dynamics Corporation literally did not exist one decade ago.

Its products today range from supersonic bombers to anesthetics for surgery; from vehicles to carry man into space to coal for use of industry; from jet passenger planes to concrete for roads and buildings; from ballistic missile-firing, nuclear-powered submarines to electronic telephone equipment. Its spectrum includes nuclear reactors, extracts and flavors for soda fountains, machine tools, high-fidelity stereophonic equipment, electric motors, and intercommunication systems.

Its interests range from rocketry to chemistry, meteorology to fusion, metallurgy to biology, electronics to human engineering.

To look at the capabilities that made this growth possible, let's start with the nuclear submarine.



Until the mid-1950's submarines were still not true undersea vehicles. They remained essentially surface vessels with the ability to submerge periodically.

Nuclear power for propulsion made the submarine potentially capable of sustained operations anywhere under the ocean's surface, with virtually unlimited range and high undersea speed.

To transmute the potential into

reality, the United States Navy turned to Electric Boat Division of General Dynamics. Electric Boat built the Navy's first submarine in 1900, and much of its undersea fleet since. It has been the designer and builder for almost all the prototype nuclear submarines of the United States Navy. The breakthroughs have stacked up cumulatively since 1955: the Nautilus, the first nuclear-powered vehicle of any kind; the Skipjack, whose shark-shaped hull represented the marriage of a true hydrodynamic design with nuclear power and provided high speed and improved maneuverability for submarines; the missile-firing George Washington and Patrick Henry, which converted the submarine from its role as a limited tactical weapon to one of a strategic deterrent.

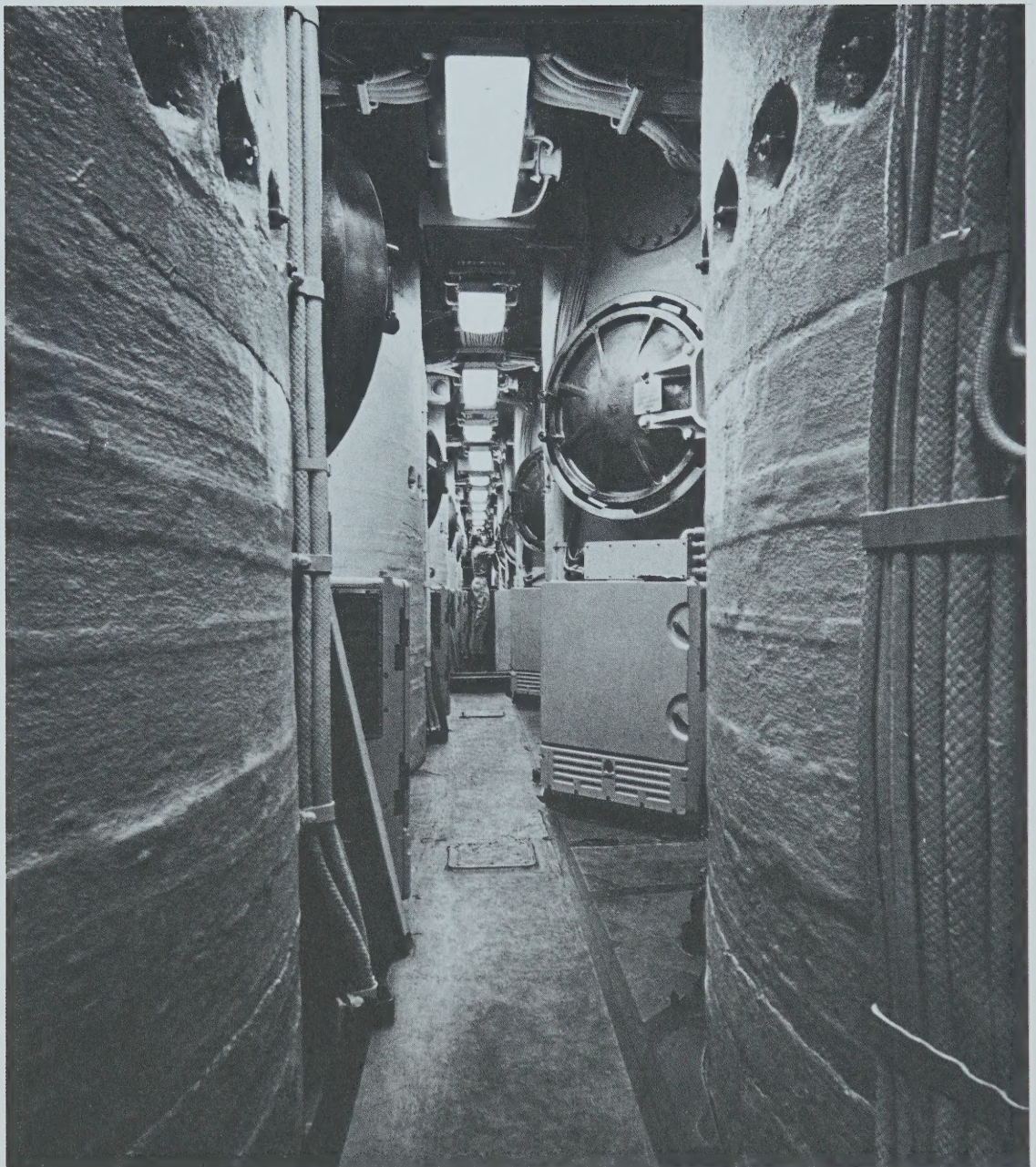
But first answers had to be found.

The nuclear submarine is literally a city under the sea. In a length often not exceeding 100 yards, it must be a place in which 100 men can live and work, cut off from contact with the rest of the world for months at a time, yet it must also be a weapon with which to fight.

The ship must carry full provisions for more than 90 days. It must contain engines to propel it and a nuclear reactor, with its shielding, to power it. It must carry sonar and radar to find the enemy and a weapon system with which to attack and to defend itself.

A submarine has just one-third as much room in which to put things as a surface ship of equal length—and no deck space. Yet into this cramped area must also go facil-

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The gallery of missile tubes in a Polaris-firing submarine, known to the crew as Sherwood Forest, houses 16 ballistic missiles.

ities for cooking and feeding and sleeping; for light, heat and air-conditioning; for washing machines and motion pictures; for elaborate interior and exterior communications systems; for massive electronic computer systems for control and navigation; for oxygen production and water desalinization. Each component and the entire complex must operate with absolute reliability.

With the Nautilus and the nuclear ships that followed her down Electric Boat ways, this set of problems was solved.

For the speed and maneuverability of a Skipjack, designers looked to the natural shapes of the sea. Every protuberance that could interfere with her true hydrodynamic form was smoothed off. Even her anchor was designed in a mushroom shape to cleave to the hull, presenting an unbroken streamline to the sea.

For the metals that can withstand the stresses of high speeds at great depths, new techniques of metalworking were needed. Metallurgists worked out ways to make "impossible" clean welds on stainless steel piping for nuclear systems. New electrode-flux combinations were developed to create a sound bond with no weld cracks for high-strength hull steels.

For the livability needed in ships submerged for months at a time, engineers achieved feats of compression. Bunks were designed with individual lighting and music outlets, more space for personal gear. Equipment was installed to provide unlimited fresh water for drinking and bathing, to keep air fresh and temperature constant.

Capacity for frozen food supply was increased.

The mating of the nuclear submarine with the ballistic missile created the need for still greater technological achievement. The newest missile-firing submarine must have all the capabilities of its predecessors—and must, in addition, be able to carry, service, guide and fire sixteen nuclear-tipped missiles.

Keeping a submarine properly trimmed is always a problem. For its missile submarines, the Navy added a further requirement—the ship must be able to fire its full complement of missiles at intervals of only one minute each and maintain stability under gale force turbulence.

At the moment the missile leaves the tube, an equivalent volume of water, which weighs considerably more, rushes in. Giant pumps in the hull simultaneously expel an amount of water equal to the difference in weight. Tons of water leave or enter the ship in a matter of seconds. Yet the ship never loses her stability; she is ready to fire again within the specified limit of one minute.

Nothing like a ballistic missile submarine had ever been built before, but the urgency was great. General Dynamics built the George Washington, from contract award to commissioning, in just 24 months.

At its yards in Groton, Connecticut, General Dynamics has not only designed and built these nuclear ships but also has been responsible for the installation and testing of their integral parts. In the process, it has pioneered in areas

normally unrelated to traditional shipbuilding skills: sound and vibration control; electronic navigation; biology for life-support systems; human engineering to make it possible for men to work, live and fight under conditions of strain for long periods.



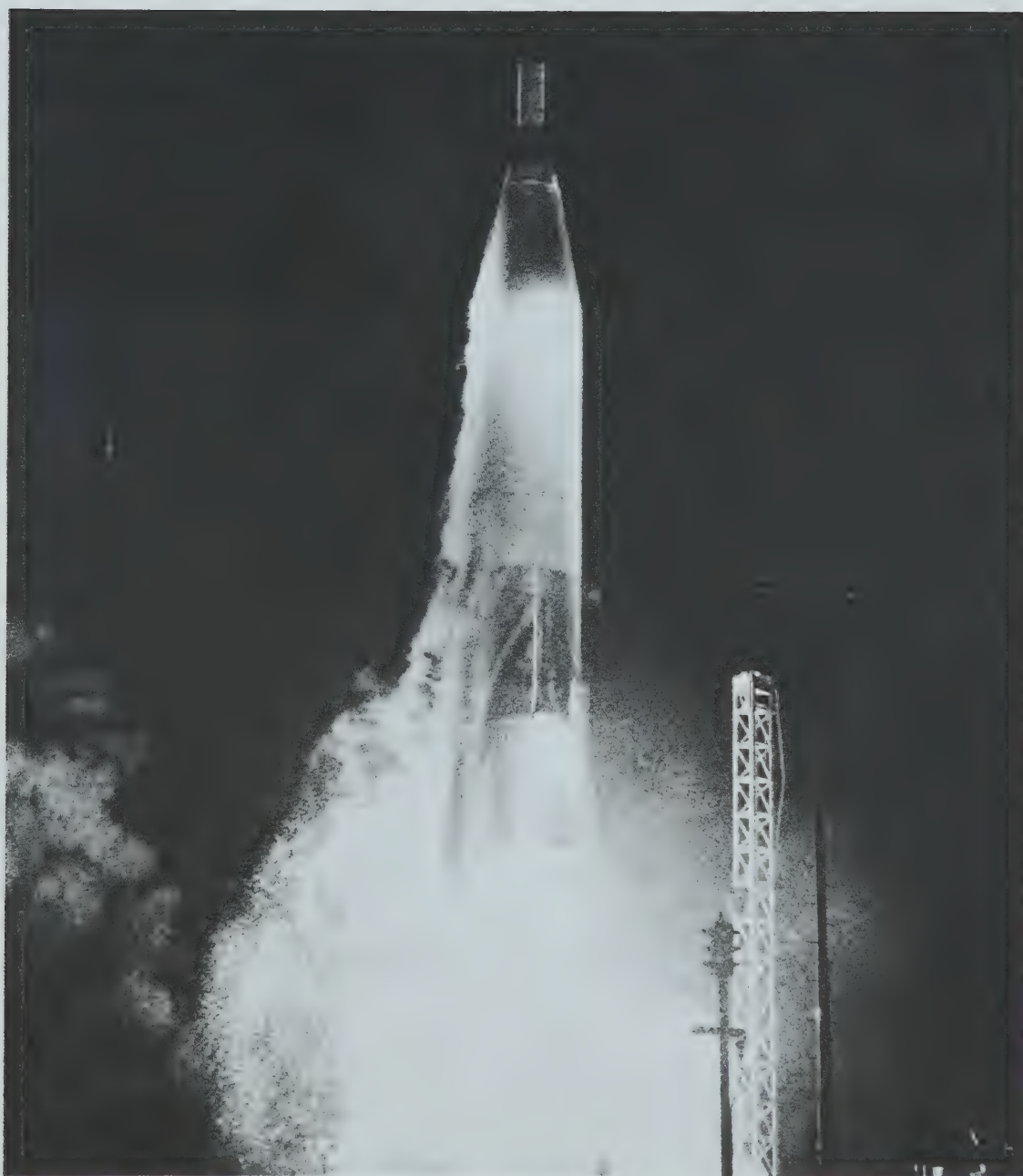
Atlas is the first of the free world's intercontinental ballistic missiles. General Dynamics, through its Convair Division, fabricates the airframe, assembles and tests the missile.

Already operational at two bases, Atlas by the end of 1962 will be standing ready at 129 launch sites at 11 Air Force bases.

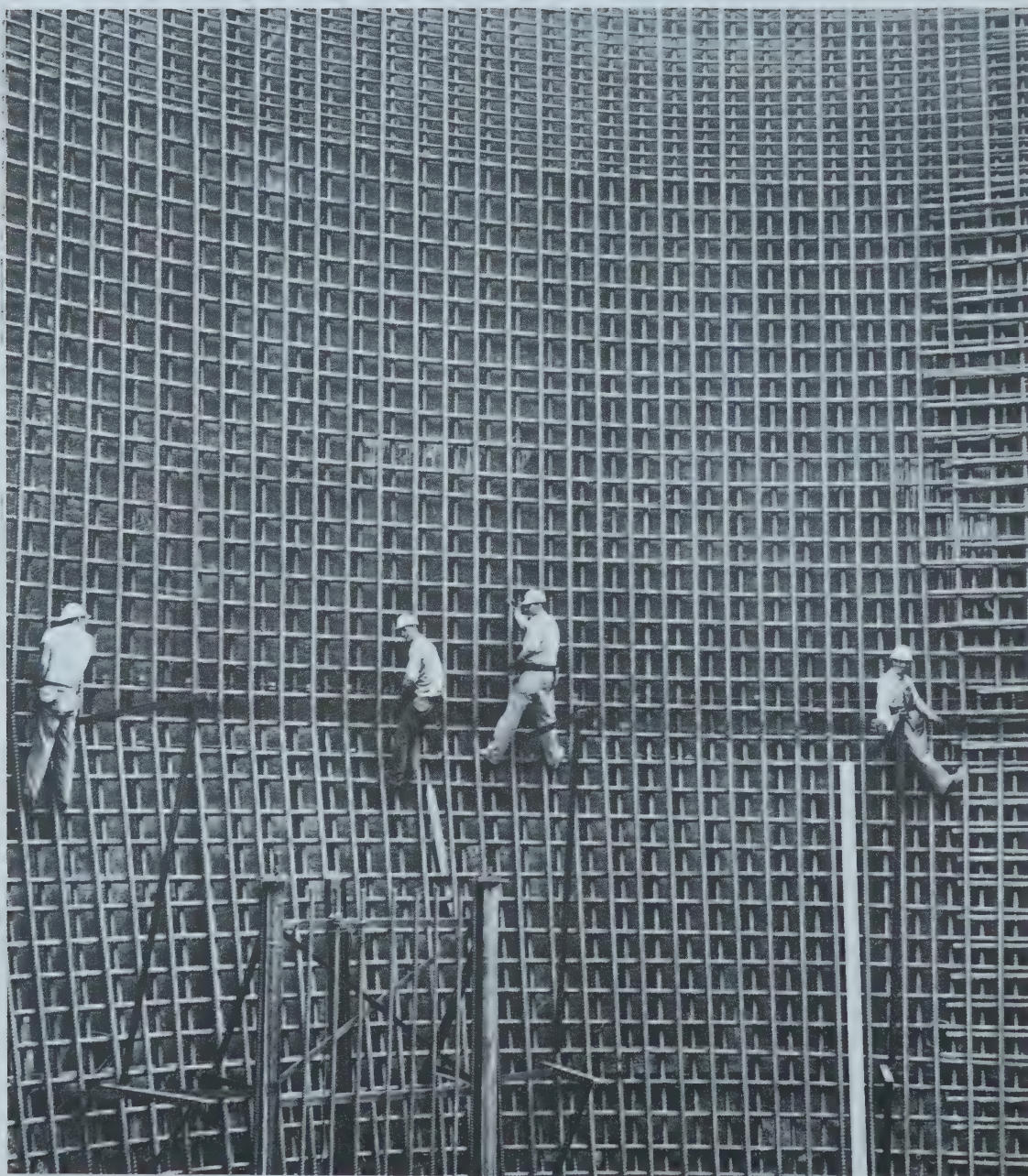
Eighty-two feet tall, weighing 130 tons, Atlas is capable of hurling a hydrogen warhead more than 9,000 miles with devastating accuracy. Designed, tested, produced with unprecedented urgency, Atlas reached operational status in just four and a half years as a major deterrent weapon in the arsenal of the United States.

The Atlas is fired from the ground and, in a brief powered flight of less than five minutes, is accelerated to about 17,000 miles an hour. Then its engines shut off. From there on, the missile is in a ballistic trajectory, hurtling toward its

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Atlas missile 44-D, similar to missiles now in operational readiness with the Air Force, starts on a successful flight.



Construction workers at Schilling Air Force Base position reinforcements for concrete Atlas silo; an early step in a complex task.

objective thousands of miles away. It will hit a target well within two miles of its point zero.

In the research program that led to Atlas, three key innovations were developed which have since become universally accepted as part of the art of rocketry:

1. The first swiveling engines for directional control;
2. The first integral tanks, with the skin of the missile serving as the wall of the propellant tanks;
3. The first separable nose cone.

The only previous long-range rocket, the 200-mile German V-2, had been controlled by graphite rudder-like vanes in the exhaust. The technique was clumsy and cut engine efficiency. Convair engineers, designing the MX-774 research rocket, hit on the idea of swiveling the rocket engines themselves to gain directional control, and proved it out on early test rockets. On the Atlas, the technique was further refined to allow the engines to gimbal.

The eventual Atlas airframe, a monocoque of tough steel—thinner than a dime but with a tensile strength of 200,000 pounds to the square inch—represented a further design breakthrough.

Engineers had already shown that the wing of an airplane could be filled with fuel. They applied to the Atlas a similar integral fuel tank technique. The airframe of the missile itself became the wall of the propellant tanks, effecting a substantial saving in weight. When empty of fuel, the skin could be kept inflated like a giant metal balloon with small amounts of gas.

The third innovation was the sep-

arable nose cone. Earlier rockets and missiles had been forced to carry the tanks and engines that got them started all the way to target. But the sole purpose of Atlas as a weapon is to thrust a warhead to a predetermined point in the sky. It then breaks free, sending the nose cone, the warhead, to streak alone to the enemy target.

These design breakthroughs were just the beginning. The Atlas as a missile is an infinitely complex total of some 100,000 parts. Moreover, by itself Atlas is just one part of a total weapon system. It must be serviced, fueled, fed target information and launched. In many respects, the missile is like a bullet—useless unless fired by a weapon.

As systems integrator for Project Atlas, General Dynamics, from its Convair/Astronautics plant outside of San Diego, California, builds the airframe, the autopilot system and various components; assembles and checks out the missiles; conducts both captive and flight tests; activates new Atlas bases, and trains Air Force personnel who will man the operational bases, which are under the Strategic Air Command.

In normal development of a weapon system, the steps of design, system testing, flight testing, final design changes and production follow in sequence. But the normal development of such a system in the past has averaged seven years or more. For Atlas, that time was cut by more than a third through a requirement for "concurrency." All the steps were overlapped to save time.

Production facilities were ordered before the first missile had been built; design of the operational bases was started before the first test flight; production was increased early in the flight test program, and operational bases were under construction midway in the research and development program.

The first full-range flight went more than 6,000 statute miles on November 28, 1958. By 1960, the standard Atlas D was being successfully fired 9,000 miles on target. During a 20-month research and development program sponsored by the United States Air Force to prove out the missile as a weapon system and space booster, 51 Atlas D missiles were fired. Only seven were unsuccessful. Currently a new and more advanced model, the Atlas E, is beginning its testing.

Building the total ground support system, of which the launch complexes are only a part, is nearly as big and as difficult an undertaking as designing and testing the missiles.

Missile bases, for instance, have created fantastic new requirements for construction standards. Building foundations must be aligned to the precision tolerances of fine machinery. Electricians must install miles of wiring with the knowledge that one faulty circuit will knock a missile out of action. Fuel storage tanks and loading lines must be assembled to hospital sanitary standards.

In early "soft sites," some of which are now operational, the structure for one emplacement contains 129,000 tons of steel and con-

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Advanced Terrier surface-to-air missiles, anti-aircraft protection for the fleet, stand at the ready on the USS Preble.

crete; its control center has nearly 4,000 miles of electrical circuitry, enough to provide a telephone exchange for a city the size of Cheyenne, Wyoming. Newer "hardened" complexes, called silos, call for building into soil and rock a 175-foot-deep cavern to house the missile, its fuels and other service requirements, the blockhouse to control its flight, and facilities to keep the missile prepared to fire on a few minutes notice, today or a year from now.

But the ICBM, with its thermonuclear warhead, is an instrument of total war. Equally vital to the safety of this nation are weapons to support a tactical defense in the event of "small wars." At Convair/Pomona, General Dynamics operates the nation's leading research, development and production facility for such tactical guided missile systems as Advanced Terrier, Tartar, Redeye and Mauler.

All air-defense missile systems have at least one thing in common: they must be capable of fast reaction.

An attacking vehicle has all the advantages of surprise and maneuverability. The defending missile must be able to intercept swiftly and surely. It must take to the air the moment the enemy is detected; and to catch and kill it must fly faster and maneuver more adroitly. It must counter, in flight, every evasive trick that the attacking vehicle will attempt.

As a class, the newer generations of defensive missiles are highly sophisticated devices. Powerful rocket engines with high thrusts are required to accelerate them;

pounds of electronic gear give them the necessary "intelligence." Yet these missiles must be both small and light, and rugged enough to be fired by personnel with limited technical training.

An example is Advanced Terrier, a supersonic surface-to-air guided missile which is now the Navy's principal fleet weapon for anti-aircraft protection.

Guidance commands come from an electronic brain packed within the missile. A computer on the surface tracks the target, instructs the radar transmitter where to direct its signal. The weapon's "brain" directs the missile along the pencil-thin radar beam until Advanced Terrier has met and destroyed the target.

Tartar has a similar mission, but is smaller and designed specifically for shipboard use on destroyers and other vessels where space is a problem. Tartar, however, has a homing-guidance system which permits the missile to "follow its nose" rather than a ground-based radar beam.

Both of these, however, are sizable. Advanced Terrier, including its booster, is 27 feet long. Tartar is 15 feet long. But the foot soldier also needs protection from enemy aircraft. Redeye is the infantryman's own private anti-aircraft missile. It is about 3½ feet long and 2¾ inches in diameter, and weighs 16½ pounds. He can carry it into battle under his arm and fire it from his shoulder.

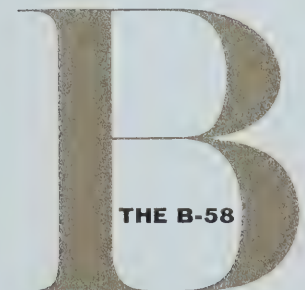
Redeye searches out its target by following the heat rays given off by any fuel-burning aircraft. An electronic circuit directs a set of steering fins to keep the missile

on an intercept course.

Redeye has a dual-thrust solid propellant engine with provisions for protecting the gunner from its blast.

In a less advanced state of development is Mauler, a highly mobile battlefield air defense system designed to knock down enemy close-support tactical missiles as well as jet aircraft. As an all-weather, completely integrated weapon system, it can be mounted in a military tracked vehicle, and be able to deliver highly accurate fire even while on the move itself; or it can be dropped by parachute or helicopter into field position.

Each Mauler unit is to be able to fire and move with complete independence. Each will contain its own power supply, target detection and electronic fire control equipment, as well as its own battery of missiles.



On August 1, 1960 a revolutionary aircraft became operational as part of the deterrent force of the Strategic Air Command. Six weeks later, it won first place for radar bombing in SAC's annual combat competition. Five months later, it broke six world's speed records — five of them formerly held by



The Air Force B-58 Hustler supersonic bomber became operational during 1960; a few months later it broke six world's speed records.

Russian planes — by flying 1,284 mph over 1,000 kilometers and 1,061 mph over 2,000 kilometers. The plane is the supersonic Air Force B-58 Hustler, produced by the Convair Division at Fort Worth, Texas. The B-58 is the free world's newest, swiftest and most versatile long-range bomber. Built to deliver nuclear bombs at intercontinental distances with pinpoint precision, it can penetrate to targets from above 60,000 feet, hurtling at double the speed of sound, more than twice as fast as any other bomber in America. Alternatively, it can hug the ground at 500 feet, going faster than a .45 bullet, to duck under an enemy radar net.

The Hustler is the latest of a long series of military aircraft with which Convair Division has served the United States. The earlier names have long been famous: The Catalina Flying Boats, the B-24 (Liberator) of World War II, the ten-engined B-36, the F-102 all-weather supersonic interceptor, and its advanced brother, the F-106, which holds the 15-to-25-kilometer speed record of 1,525 miles per hour.

To meet the Air Force requirements in the early Fifties for its first supersonic bomber, Convair Division proposed an unconventional plane: a relatively small aircraft for a bomber, with a delta (after the triangular shape of the Greek letter Delta) wing and a disposable under-fuselage pod to carry the payload. The proposal was accepted by the Air Force, which also designated Convair as weapon system manager.

As weapon system manager, Convair was directed not only to de-

sign, build and assemble the new airframe—but was also given responsibility for overseeing development and procurement of all major sub-systems, except the government-supplied jet engines. The complete weapon system included, as well as the vehicle, the ground equipment and logistic support needed to keep it ready for combat.

Early in the development of the B-58, the National Advisory Committee for Aeronautics discovered the area rule, a method of overcoming the considerable rise in drag at the speed of sound. Convair engineers first applied it to the F-102 all-weather jet interceptor, later to the F-106 and the B-58 Hustler.

On all three aircraft, the area rule application is most apparent in the wasp-waisting of the fuselage. On the F-106 and B-58, the effect is to increase the range of the two planes by reducing the amount of power (and fuel) required to overcome the drag rise near the speed of sound. The area rule has a lesser but still significant benefit in reducing drag on both planes at speeds as high as Mach 2.

Design of the B-58 structure itself required new concepts. One of these was the use of large sandwich panels for the primary structure.

The "sandwich" consists of a cellular honeycomb core, bonded between two thin, tough skins. The core may be glass fiber or metal; the skins, aluminum or stainless steel. The bonding process may employ either organic adhesives or brazing.

Sandwich material is structurally

efficient, has a high strength-to-weight ratio, provides aerodynamic smoothness, and is resistant to sonic fatigue failure. Its use helped hold the B-58's structural weight to only 13.8 per cent of maximum gross weight (compared with a low of 19.8 per cent among previous operational bombers). As a result, nearly two-thirds of the B-58's maximum takeoff weight is fuel.

Sandwich panels comprise some 90 per cent of the Hustler's wing surface. Stainless steel is used in areas subject to severe loading and heating (such as the elevons). Since the entire wing is used as a fuel tank, glass fiber honeycomb is the core material used most extensively; being a poor thermal conductor, it insulates the fuel from external heat.

The Convair-pioneered delta wing added further to the aircraft's performance flexibility. The large triangular shape provides both the wing thinness and sweep-back required for supersonic speed at high levels without sacrificing the wing volume needed to carry large quantities of fuel. At the same time, the wing affords exceptional structural rigidity and stability when the plane is flying low-level missions in the turbulent air only 500 feet above the ground.

Until the B-58, bombers were designed on the same principle as boxcars—a body large enough to surround the cargo. The B-58 broke with that tradition; the fuselage was made only large enough to house the crew (three men) and the essential flight systems. The entire "bomb bay"—in the form of an external disposable pod—can

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Air Force's SAGE air defense system makes use of CHARACTRON shaped beam tube in electronic consoles to display area situation.

be dropped, letting the Hustler fly home lean and fast.

Today, the B-58 is probably the most flexible military aircraft in the world. As a rocket-launching platform, it achieved the first supersonic air launch of a ballistic missile. In another approach it has shown its feasibility as a launcher for a satellite-inspection vehicle.

In spite of the availability of missiles—and in some ways because of the very frightening power of the ballistic missile with a thermonuclear warhead—the manned bomber now is more important than ever. A missile cannot be recalled once it is launched. Bombers can take to the air at the report of danger, but can be called back if the report proves false, avoiding war by accident. Today, the strategic doctrine of the Air Force is that a mixed force of bombers and missiles will be needed indefinitely.



When strategic decisions must be made in minutes, tactical decisions in seconds—and equipment must function reliably in terms of millionths of a second—electronics becomes an integral part of every decision and every weapon. As part of its over-all status as a weapons producer, General Dy-

namics has built a tremendous capability in a field that barely existed one generation ago, when electronics still meant largely radio.

Electronic equipment guides a missile to its destination, controls its operation, tracks its flight, transmits its test data to ground stations, and reduces that data to meaningful use. Human reaction times, too slow to cope unaided with the incredible speeds of modern aircraft, are aided by electronic devices. Ground and sea warfare depend on electronics for communication and reconnaissance.

In one decade, modern weaponry and modern electronics—two sides of the same coin—have developed together. The weapons producer has perforce become an electronics producer.

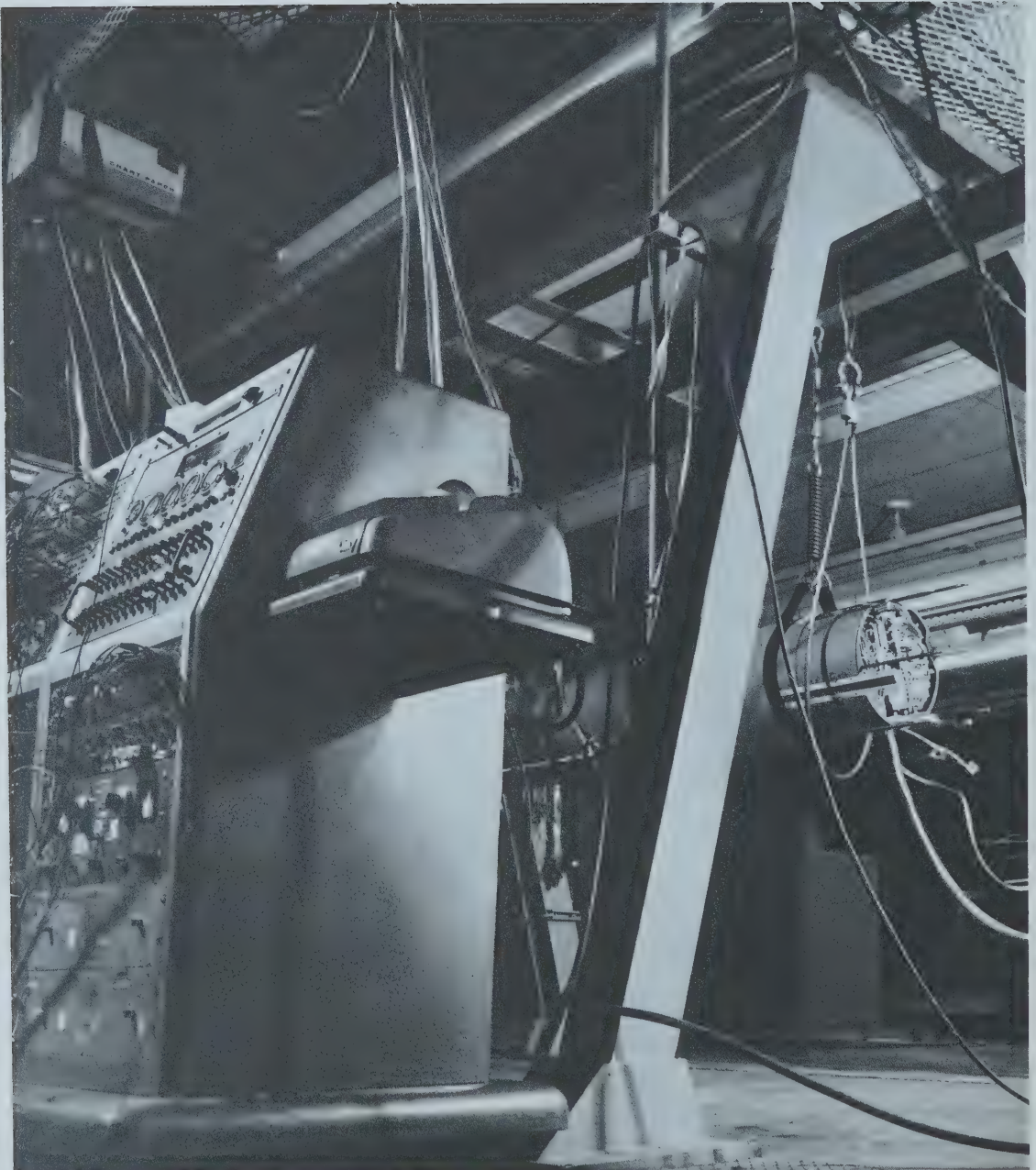
The list of military electronic products made by General Dynamics is already an impressive one, ranging from airborne computers to control aircraft in flight through an assortment of communication and surveillance equipment, automatic testing equipment, missile tracking systems, radar of all kinds, and anti-submarine warfare equipment.

The interrelation between electronics and a weapon can be seen with the Atlas. Its original design was worked out with the aid of giant computers. In the course of its construction and testing, its sub-systems are checked and rechecked with electronic test equipment. During shipment of the missile from San Diego, where it is built, to the base where it is to be flown, electronic sensors

keep a constant check on the internal gas pressure that keeps the missile's skin rigid. In preparation for test flight, an electronic countdown quickly checks all of the missile's guidance, communication, telemetering, and emergency destruct systems. From the first second of flight, electronic components guide the missile to its destination, control its fuel flow, tell the nose cone when to part company with the rest of the missile, and radio back data from instrumented points in the missile. The data, recorded on some 10 miles of magnetic tape, include temperatures, vibration, valve position, acceleration, fuel flow.

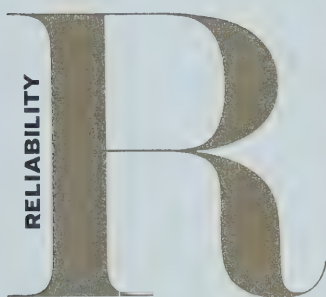
When the first Astronaut goes into space as part of Project Mercury, scientists on the ground in the General Dynamics-designed-and-built control room at Cape Canaveral will receive, on giant visual display panels, immediate information about the second-by-second progress of the space vehicle and the physiological reactions of a man in space.

On the ground, new theories of warfare are based on broad dispersal of military units—which increases the need for effective communications to coordinate actions. General Dynamics supplies the Army with light, flexible and reliable electronic communication systems, both telephonic and radio. With its BASIC battlefield information system, tactical ground operations can be revised. Forward scouts carry tiny data transmitters; button-punched information on enemy dispositions and movements can be sent in a millisecond "burst". This field in-



Test equipment checks a tactical missile. Reliability requirements of modern weapons make rigid quality control necessary.

telligence will appear visually on a rear area receiver similar to a television set to give command personnel timely and accurate information about a tactical situation on which to make decisions.



One factor common to all General Dynamics systems lies in an article of faith — reliability.

A major military weapon must work. If it is ever needed, there will be no time to correct failures after they occur. Reliability is planned into a product from its very conception.

The 100,000 parts of the Atlas come from 3,500 different suppliers. Failure of an eight-cent cotter pin can destroy a missile—and its mission — as effectively as a breakdown in one of its giant motors. The B-58 contains over 6,000 tubes, diodes and transistors; one defective electrical circuit can stop a supersonic plane, racing a mile every 3 seconds, as effectively as anti-aircraft fire. A nuclear submarine carries the lives of 100 men with it the very first time it submerges.

A weapon system is only as good as its reliability—its ability to work perfectly in every particular, whenever it may be needed.

General Dynamics builds this sort

of reliability into every one of its systems. The very fact that supersonic aircraft, intercontinental missiles and nuclear submarines—all tremendously complex systems—could be brought into being successfully at one time, along with a host of other concurrent production and research activities, is clear indication of sound engineering and management.

For at General Dynamics, reliability is a management function. At its divisions, responsibility for reliability starts not with an inspector or an engineer but with the division president.

Reliability begins with goals—the mission requirements, operational objectives. Imaginative concepts are matched against sound engineering principles. Every component and sub-system is pre-checked through intensive computer programs, as individual items and in relation to mathematical models of the total system. Preliminary studies for one aircraft involved over 1,300 hours of computer time—the solution of more than a billion arithmetic problems, equivalent to almost 20 million man hours of figuring. Parts are redesigned whenever necessary until predictions agree with the requirements of the system. Only then are components specified for production.

Subcontractors and suppliers are selected with extreme care. Selection depends on proven technical and management abilities, past performance in quality work, and financial stability.

Whether purchased or directly produced, components are subjected to exhaustive tests. Among these tests: X-ray, ultra-sonic

probe, vibration and fatigue, tensile strength and hydraulic pressure, reaction to environmental conditions of extreme heat, extreme cold, and the high vacuum of space.

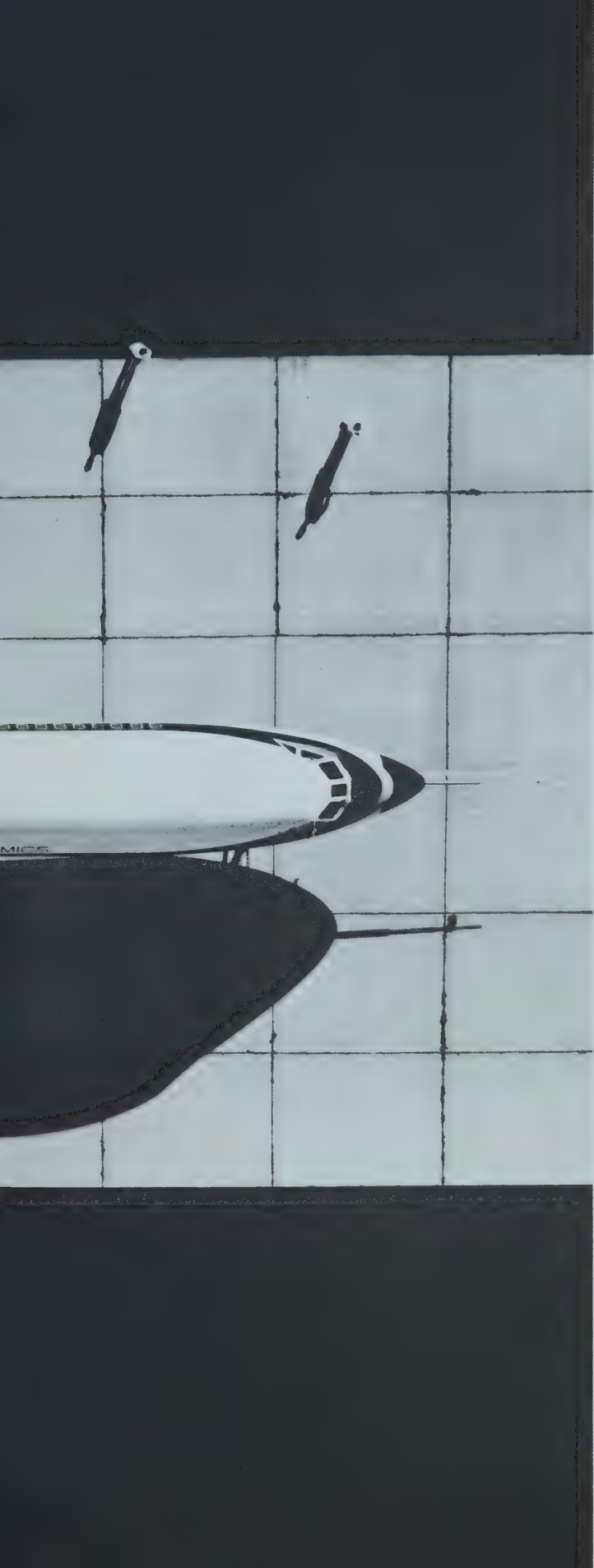
During fabrication, a quality control program as meticulously worked out as the weapon design itself is employed to weed out probability of error. Parts are inspected and tested individually. As parts are combined into sub-systems, these are tested under operating conditions, as are larger systems and then the final weapon itself. Special automatic testing equipment checks vital systems, and is in turn constantly checked itself for possible malfunction.

As one indication of the rigor of this program: at Convair/Astronautics, which assembles and flight-tests the Atlas, over one third of all employees of the division are involved in testing procedures at some level.

The potential for error can never be entirely removed—but as far as possible, General Dynamics tries to do just that. General Dynamics never considers that "it is just selling a product." As a philosophy, it feels that it is producing, in partnership with the Government, the vital items that may save lives and perhaps the very existence of the free world. Reliability, from top management to production-line, is a crusade.

Does it work? One evidence comes in a statement from the Navy: "Terrier is so reliable that if we have a failure on a missile test, we check the test equipment to see that it is working properly before we start checking the missile."





The Conqair 990, world's fastest passenger aircraft, is readied for flight.

Section

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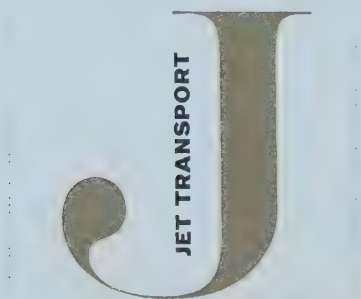
CAPABILITY FOR INDUSTRY

Discoveries and techniques that make possible great weapon systems often have ultimate application to industrial and consumer needs.

Aerodynamic research for military planes has resulted in new high-speed jet liners for passenger travel. The development of the electronic computer for Government uses has brought about a complete revolution in the processing of information. The Manhattan Project opened the way to atomic power for peaceful uses.

General Dynamics serves industry as well as defense in its habit of research. It is as important to think in terms of the needs decades hence for industry and the consumer as it is for military requirements.

As General Dynamics has met, and will continue to meet, the need for new and more effective weapons to safeguard a civilization, so also it meets the call for new and better products with which to enhance that civilization.



The newest of jet passenger transports — General Dynamics' Convair 880/990 series — are the fastest commercial aircraft in the world.

The Convair 880 cruises at 615 miles an hour. The present southern transcontinental speed record was set when Delta Air Lines took delivery of its first 880 in February, 1960. The plane raced from ocean to ocean — from San Diego to Miami, a distance of 2,267 miles — in 3 hours, 31 minutes and 54 seconds.

Since the end of World War II, Convair Liners have earned an enviable reputation for dependability, ruggedness and economy. Over a thousand of the Convair 240/340/440 series of twin-engine propeller planes were made, and most are still in use.

General Dynamics' commercial planes have staked out a particular market — the medium-range flight which represents the bulk of all air traffic. When the jet age came in sight, General Dynamics planned its jets for that market.

For its new planes, it set these specifications: the aircraft had to be fast, fly so close to the speed of sound that they could not be obsoleted short of the arrival of true supersonic commercial transport. They had to be comfortable for passengers. They had to serve the medium-range market, operate out of most commercial airports that now handle four-engine piston planes. They had to be rugged; the stresses from the frequent take-offs and landings of medium-range traffic are more punishing than those of actual flight.

To build speed into the plane, designers picked a new jet engine, a commercial version of the engine that powers the supersonic B-58. For the plane itself, they created the thinnest of all jet air-

liner wings, with an unusually large surface.

Into the wing, they built extra strength through a system of three main spars interconnected by bulkheads and trusses, thus distributing the structural load. The large wing supplies another bonus: fuel capacity for operation on long-range non-stop flights, and fewer servicing requirements for the aircraft in several-stop, medium-range service.

For comfort, they built in the quietest passenger ride of any four-engine jet by using extensive glass fiber padding, sound-dampening tape, and heavy-gauge aluminum alloy in the fuselage.

Toughness was verified with one of the most punishing test programs ever devised. An entire fuselage was hung by stub wings in a giant water tank. Hydraulic rams pushed the airframe up and down 62,000 times to simulate landing and take-off stresses, equivalent to the effect of more than 20 years of airline service.

Though the 990 strongly resembles the 880, it is larger, has a longer range — and will be even faster. The extra speed comes from the combination of more powerful aft-fan engines, and from a visible feature that distinguishes the 990 from all other aircraft — its speed capsules. These capsules — "aerodynamic anti-shock bodies" — roughly resemble overturned canoes placed on the wings. When a plane flies close to the speed of sound, air passing over the curved upper surface of the wing reaches supersonic speed and develops shock waves that increase drag. The capsules smooth

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The swing tail of the Canadair Forty Four permits straight-in loading, cuts handling time and cost for commercial air cargo.

the airflow to lessen the shock wave.

Although General Dynamics' jet transports can serve route segments varying in length from 300 to 4,300 miles, there still remains a need for shorter-range aircraft to equip "feeder" airlines serving smaller communities. The turbo-prop-powered twin-engine Canadair 540 fills this role. It combines high speed with passenger comfort and the convenience of integral loading ramps.



By air, transcontinental freight shipments can be made in one day, compared to an average shipping time of three weeks by other means of transport. Yet although "time is money," for many years air freight, which can save both, has been more discussed than used. Planes and flight schedules have been designed for people. Cargo has been, at best, an incidental.

Over-all volume of air freight has increased steadily, but it still represents less than 1% of all the freight moved in the United States last year. Air freight remained small because the right planes were not available; the right planes were not built because volume was low.

Beginning with 1961, that picture could change significantly. The Canadair Forty Four, the first plane specifically designed for commercial air freight, will go into service with three United States all-cargo air lines.

General Dynamics decided to break the cycle because it was convinced that air cargo—as with passenger traffic back in 1932—needed only the proper plane.

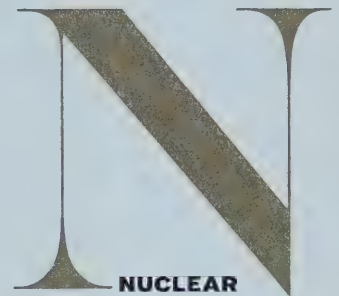
The swing-tailed turboprop Forty Four is 136 feet long, and capable of lifting more than 30 tons. It flies at better than 400 miles per hour, with a range up to 6,000 miles.

The entire tail section swings open more than 100 degrees. Cargo can be run in fast in straight-line motion. With an integrated ground loading system and full palletization, the plane can be unloaded, reloaded, and off the ground in one hour—compared with six hours for passenger planes converted to cargo work. Ease of loading, combined with low direct operating costs—estimated at 4-5 cents per ton mile—will cut the expense of carrying freight sharply. Customer airlines which have ordered the Forty Four have already applied for rate reductions, cutting as deeply as 70% below former levels.

These new rates in themselves will be competitive with many ground transportation tariffs. But air freight promises economies far beyond changes in current rate structures.

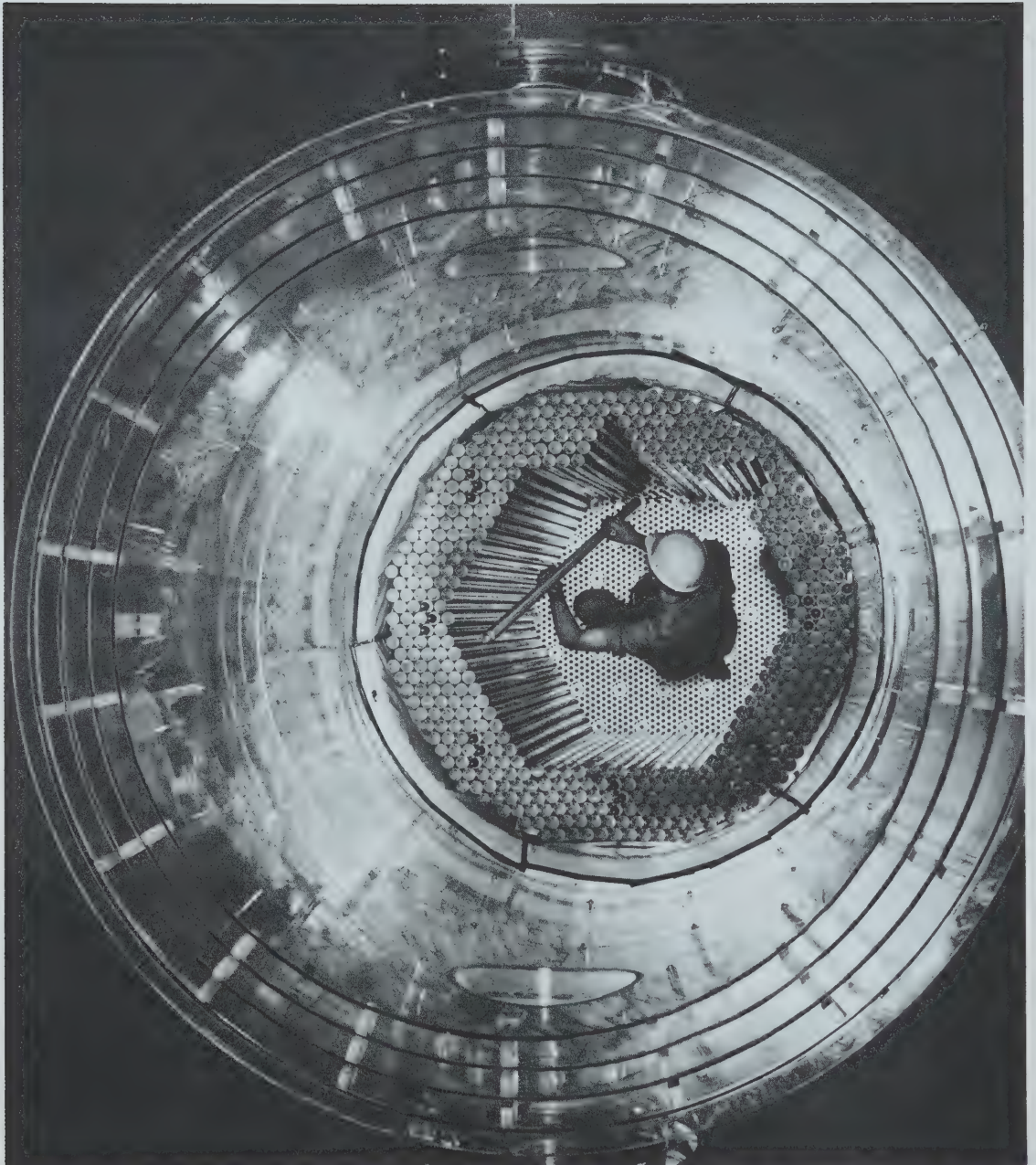
If a manufacturer can be assured of regular, on-time, one-day delivery of his product to any point in the country, the need for warehousing and distribution centers

drops sharply. Production can be keyed closely to orders, inventory and interest costs reduced, and redundant handling charges eliminated. With these additional factors considered, true cost of air freight should drop far below that of any other means of transport.



Accelerating population growth plus increased per capita use of electricity means that power will ultimately be required from every source through which it can be developed—including nuclear power plants. The Sixties is the decade of decision on which types of atomic power plants will be capable of generating electricity at costs equal to, or even less than, plants based on fossil fuels. As the most direct route to economic atomic power, General Dynamics, through its General Atomic Division, is developing high-temperature, gas-cooled nuclear power reactors both for central station power and propulsion.

Modern thermal power plants burn coal, oil or gas to produce the high-pressure and high-temperature steam required by modern high-efficiency turbo-generators. In an atomic plant, nuclear reaction rather than burning fossil fuels supplies the heat.



Simulated fuel elements are loaded inside coolant flow test installation for high-temperature gas-cooled reactor.

Efficient use of nuclear fuel for power generation also requires that this energy be extracted at high temperature and transferred to another medium which will either heat water into steam or directly drive a turbine. General Atomic scientists and engineers chose helium gas as the most effective medium to transfer the high nuclear heat.

In the General Dynamics HTGR system for large-scale electricity production, helium gas passes through the core, absorbing the heat from the atomic reaction. The gas leaves the reactor at 1,380 degrees F, then passes to a boiler where it converts water to 1,000-degree steam at pressures of 1,450 pounds per square inch for the turbines. This high-temperature, high-pressure steam fits the requirements of modern generating equipment and can be used with existing electricity-generating technology.

Another part of the economic prospect of HTGR lies in its efficient fuel use. Generally, reactor fuel life is limited by the burning out of uranium atoms, which makes the fuel fall apart. Fuel lifetimes over two years are considered very long. In the HTGR, the fuel is mixed into a carbon matrix and does not crumble even when a great part is burned out. As a result, the fuel in the HTGR will last from three to seven years.

The first HTGR power station, a 40,000 kilowatt prototype designed to point the way to economic nuclear power, will be built at Peach Bottom, Pennsylvania. Beyond this prototype, the HTGR concept has been selected for a large-

scale development program directed toward construction in New York State of a 300,000- to 500,000-kilowatt capacity nuclear plant that would be competitive in cost with fossil fuels.

Smaller nuclear power plants, in the 25,000- to 100,000-kilowatt class, will be needed both for land-based power generation and for ship propulsion. For this purpose, General Dynamics is perfecting another high-temperature, gas-cooled system, moderated by beryllium oxide rather than carbon. The Atomic Energy Commission has awarded General Atomic Division a contract to develop and test-operate the first beryllium oxide reactor to be built for civilian power purposes.

The beryllium oxide system, because it allows fewer neutrons (neutral particles, created by the fission process, which in turn hit other atoms and cause them to fission) to escape, provides high fuel economy. In this type, the hot helium leaves the reactor at nearly 1,500 degrees and goes directly into a gas turbine, eliminating intermediate boiler systems. In a merchant vessel, the turbine can be coupled to the propeller shaft to drive the ship; in a land-based system, the closed-cycle gas turbine drives a generator to produce electricity.

The sources and forms of energy are almost limitless, and General Dynamics is pursuing many combinations of them. It has joined forces with a large segment of the investor-owned utility industry to push ahead in nuclear power production, in the study of energy from the fusion of hydrogen atoms, and in the direct conver-

sion of heat to electricity. Additional programs for the United States Government range widely from power reactors to development of thermoelectric devices to harness solar energy for auxiliary space power, to special TRIGA research and test reactors.

More than 20 TRIGA research reactors are already in use or being installed on five continents. The latest addition to this family of reactors is the Mark F "pulsing" TRIGA, which opens new research and testing opportunities wherever short, high-intensity pulses of nuclear radiation are required. TRIGA's today are being used for a wide variety of research and biomedical applications; in a number of cases they form the core of nuclear training centers set up by foreign governments.

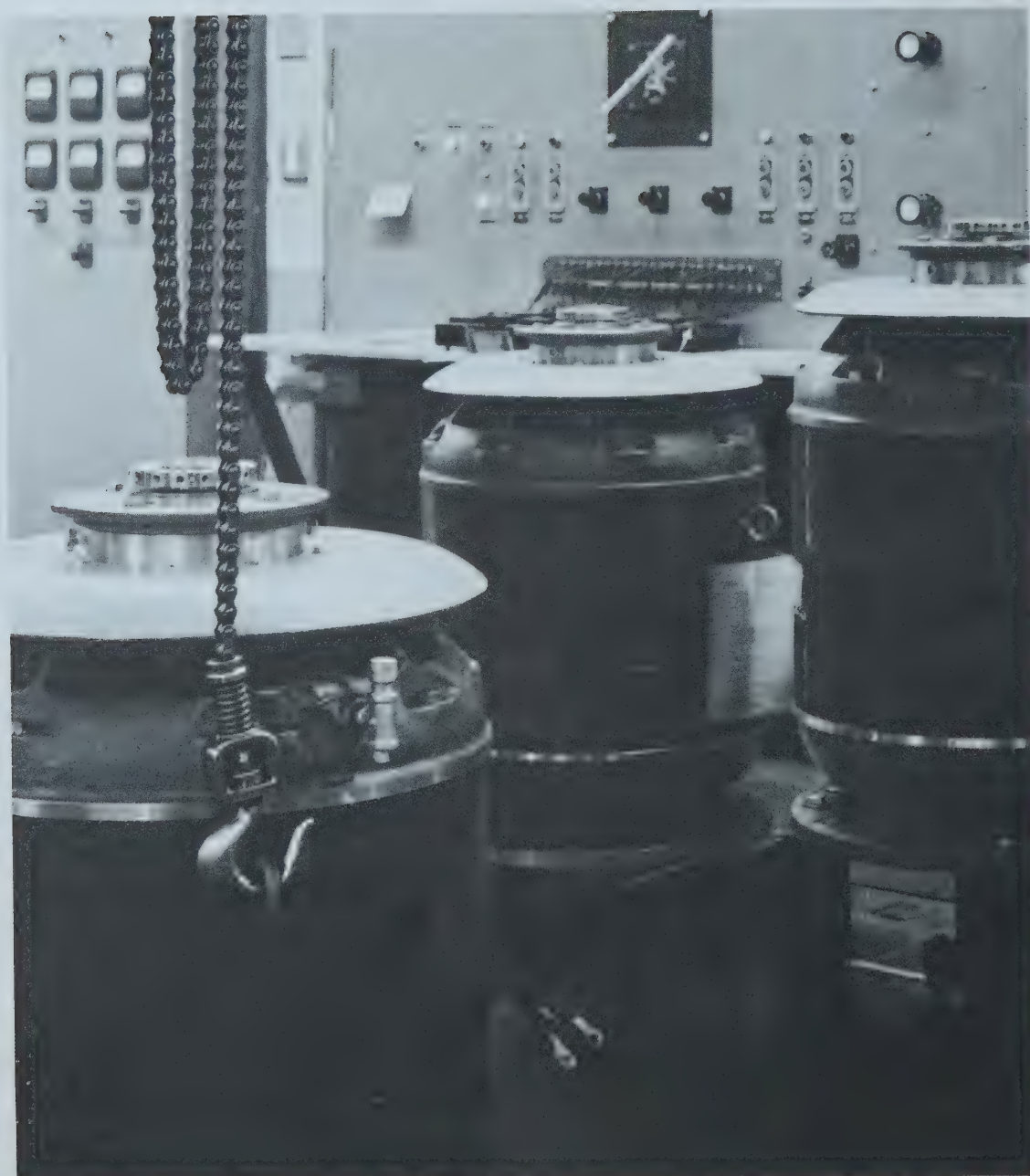
American universities which have selected TRIGA's for operation on their campuses include Columbia, Cornell, Illinois, Kansas State and Arizona. Abroad, they have been chosen by the University of Mainz in Germany, two universities in Japan, the University of Minas Gerais in Brazil, and Lovanium University in the Congo.



General Dynamics has long produced fine radios and high fidelity



Complex engineering drawings are produced on microfilm in less than one-half second directly from computer data by the SC-4020.



Advanced manufacturing techniques and electronic testing cut electric motor vibration, reducing noise and improving performance.

and stereophonic music systems under the famous Stromberg-Carlson label. But the key to modern electronics is communications and information handling—and in precisely these areas lie General Dynamics' greatest strengths.

Growing masses of data call for an equally rapid growth in the use of electronic information processing systems for control. But information processing requires more than a central computing "brain." Equally essential is finding manageable ways of receiving, and using, the results.

General Dynamics makes special-purpose computers for aircraft and missile control. But emphasis is more on devices for transmission and end use of data—the peripheral equipment that makes it possible to translate the fast output of high-speed computers into a form that can be absorbed by the human eye and mind.

Its electronic printers supply data from a central computer at up to 100,000 words or figure combinations per minute, to print mailing labels for mass circulation magazines, or utility bills, or information sent from a space satellite. A high-speed transceiver transmits electronic impulses over commercial telephone lines or microwave systems to allow data to be transferred from one location to another, or to permit computers to "talk" to each other.

Another system translates computer data directly into the charts and graphs that supply an immediate picture the researcher may be seeking. General Dynamics' SC-4020, a computer readout microfilm printer, will record data

on microfilm at 15,000 characters per second, plot permanently recorded graphs at 15,000 points per second, and eliminate the time lag and the potential error involved in plotting graphs by hand from printed computer output. Other adaptations will produce complete engineering drawings within one-half second.

Information handling has older meanings, however—the direct transmission of the spoken and written word. A high-speed facsimile transmission system can transmit a letter, a drawing, or a printed page from coast to coast in four seconds at little more cost than a first-class letter.

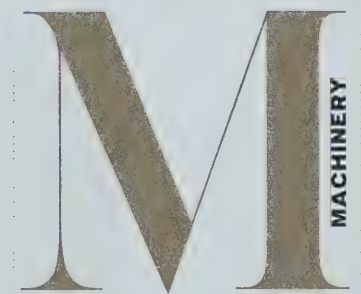
In the field of controls and instrumentation, General Dynamics has developed advanced systems for nuclear power reactors. Solid-state circuitry is employed in both nuclear and process control systems, assuring reliability and compactness.

Telephony is expanding its boundaries. New DYNALOGiC electronic switching systems will provide better telephone services at greater speed. Calls can be transferred to other phones by coded dialing; conference calls of several parties can be arranged; waiting time after dialing will be reduced to microseconds. For telephone companies, the new system solves the problem of proliferating space requirements. A 600-line DYNALOGiC system needs only eight square feet of floor space compared to 625 square feet with present electro-mechanical systems.

Faster information handling also means greater safety control

where human lives are at stake. Within the New York metropolitan area alone, with its eight airports, a total of 3,200 flights a day arrive and depart. In spite of that traffic, safety records are amazingly good—due largely to a wide range of air-to-air and ground-to-air electronic devices that make it possible to control this churning of high-speed motion.

General Dynamics, through its long association with aircraft, has been deeply concerned with aircraft safety. Electronic products designed around this one purpose include: automatic air-traffic control systems, aircraft data-link systems, both airborne and ground radar, beacon monitoring and control systems, and mobile radio transmitters and receivers.



Industry moves on thousands of unseen items. One of these is the electric motor—without it, very few wheels would turn at all.

General Dynamics, through its Electro Dynamic Division, has made electric motors for 80 years. As an essential part of machinery, the motor is generally taken for granted. But motors vibrate—and vibration creates noise.

In submarine warfare, water-borne sound which can reveal your pres-



Compressed gases are playing a growing role in manufacturing. Carbon dioxide, which this plant produces, is used in over 120 industries.

ence is a hazard—the submarine particularly requires stealth, the absence of noise, to complete its mission.

To meet Navy requirements, General Dynamics builds motors that are almost vibration-free. Key parts are tested and balanced under stroboscopic light and sound analyzers. The completed motor is so well balanced that, externally, neither sound, sight nor touch will indicate whether the motor is on or off.

Dynamics has reduced motor shaft vibration to as low as 10 millionths of an inch, a tiny fraction of the 10 thousandths of an inch standard for general non-precision applications.

For industry, lack of vibration in a motor means new standards can be applied to production machinery where extremely close tolerances are required. Low vibration means not only greater precision but less wear and a longer economic life for motors and the equipment they power. It can mean quieter factories, and a more comfortable climate for plant workers.

In another attack on mechanical noise, General Dynamics engineers at its Electric Boat Division found a way to quiet the widely-used ventilating fan.

Slotted blades in the fan make it possible for the vanes of the fan to pass through the air without creating turbulence while still moving large volumes of air. Result: a noise level only a small fraction of that created by standard fans. These "vaneaxial" fans have application wherever the requirement exists for efficient

movement of air with minimal noise and vibration.

But some problems of modern manufacturing are not solved merely by improvements to relatively standard equipment. For example, nothing was available to measure precisely the effects of acceleration and deceleration on missile parts. So General Dynamics created its own new testing equipment—and in the process, a new line of machine tools.

Dynamics engineers developed a unique pneumatic actuator they called HyGe. HyGe generates a repeatable and precisely-controlled high-energy thrust through differential gas pressure acting on two faces of a thrust piston in a closed cylinder.

This principle has been applied to a whole family of HyGe simulation and testing machines and Dynapak high-energy-rate metal forming machines. These are capable of applying millions of pounds of pressure in a fraction of a second, making solid metal "flow" and even changing the characteristics of its grain.

Dynapak forming removes old restrictions and opens new design possibilities for even such high-temperature metals as molybdenum and tungsten. Tungsten melts at 6,170 degrees F. It will retain its strength long after steel has melted and evaporated. For that very reason, it has been difficult to work. Under high-strain rates created by Dynapak, molybdenum may be formed in conventional tooling, and tungsten has been extruded into shapes never achieved before. Dynapak has even created a new class of metal

parts—forged castings. Parts are cast slightly oversize; then sized in a Dynapak die to obtain the greater strength of a forging at little more than the price of a casting.



General Dynamics, through its Liquid Carbonic Division, is the world's largest producer of carbon dioxide. In addition, it manufactures oxygen, hydrogen, nitrogen, acetylene, argon, nitrous oxide and other industrial and medical gases. These products, taken from the atmosphere or broken out of fossil fuels, are literally invisible and omnipresent.

Carbon dioxide once was identified mainly as the "fizz" in soda pop or the chunk of "dry ice" that kept ice cream frozen. Working closely with other industries, Liquid Carbonic has developed innumerable other uses. Both fresh meats and such prepared foods as instant coffee or cake mixes use CO₂ in their processing. In golf balls, the liquid center is frozen with carbon dioxide before being wound in latex. Rubber for tires and paint for houses are both improved by use of carbon dioxide.

Other gases also are playing an increasingly large role in industrial production. Oxygen-lancing



Building materials produced by the Corporation are playing a major role in the building boom that is changing the face of Chicago.

is growing in importance as a steel-making technique. Electronic components are produced under an atmosphere of nitrogen or argon. Hydrogen is a key agent in the fusing of glass and the refining of rare metals.

Perishable goods are better preserved because gases pre-cool the vehicles in which they travel. Foundry operations are revamped because carbon dioxide makes possible core and mold hardening in a fraction of the time required by former methods.

Industrial gases have already helped create a revolution in the eating habits of the United States by making possible the development of frozen foods. They are the keystone for a still newer form of food preservation — freeze drying (rapid freezing followed by removal of liquids in crystal form in a vacuum) which promises long preservation of even cooked foods without refrigeration.

Fifteen years ago, General Dynamics' Liquid Carbonic Division served about 20 different industrial categories; today it serves more than 150 different categories.



The basic principles of construction were laid down millennia ago. But in recent years, even some of

the principles have changed. Mushrooming population and greater intensity of land use demand more concentrated construction, at reasonable cost.

In southwest Chicago a huge addition to Evergreen Shopping Plaza, a 900,000 square foot shopping center, will utilize a technique to cut the total material weight of construction by almost 50% under any comparable method. The key: a unique engineering design making extensive use of Dynacore prestressed hollow-core slab, designed and produced by the Material Service Division of General Dynamics.

The prestressed cored slabs offer both strength and light weight; the hollow cores provide built-in insulation and conduits for pipes, cables and utilities; with a variety of surfaces, the slabs can be used either as floors or as walls. The technique makes possible single concrete slabs 8 feet wide, 3 feet deep, and 100 feet long which can be manufactured on an assembly line basis in advance and lifted into place quickly and easily at the construction site.

The Material Service Division is one of the largest producers of ready-mixed concrete, concrete products, sand, gravel and crushed stone. It has pioneered in new applications for reinforced and prestressed concrete and new lightweight concretes with great strength. These permit the architect far more freedom in design than ever before, without sacrificing economy.

For massive construction — dams, for instance — concrete has long been a staple. It has been the underpinning of transportation, par-

ticularly for heavy-traffic highways and airports. Today, concrete is making inroads on areas formerly reserved for other structural materials — largely because of the comparatively new technique of prestressing. By eliminating otherwise undesirable strains, prestressing makes possible enormous savings in the amount of steel and concrete required to support a given load; by reducing other materials needed, the light, strong and flexible prestressed members offer economic advantages over competitive materials. Material Service prestressed beams, for instance, now support numerous bridges on the network of new highways speeding traffic in the Chicago area.

In the Chicago metropolitan area Material Service pioneered in the use of Redi-Mix — a system of premixing concrete at a central point and in transit for immediate pouring at the construction site. That operation today has been automated extensively — electronic control systems measure out precise amounts and types of cement, aggregate, and water to create a concrete custom-designed for any specific building application.

These automated techniques, combined with new lightweight concrete aggregates developed by Material Service, produce concretes that are lighter, stronger, less brittle, and more uniform in grain. These have made possible such projects as Marina City, being built on the Chicago River at the edge of the Loop, whose twin 60-story towers will make it the tallest reinforced concrete structure in the world.





Section

3

CAPABILITY FOR THE FUTURE

The Milky Way in the constellation Ophiuchus: by Yerkes Observatory.

Quickly as change has come in the past generation—it will come even more quickly in the next. Few organizations have been able to meet the change so well as General Dynamics. Few are so ready for an accelerated rate.

General Dynamics today is a versatile complex of many specialized units, whose total is greater than the sum of its parts. In creating its great products, it has accumulated a deep reservoir of men, talents, machines—and ideas. Out of that reservoir will come the great products of the future.

Its binding spirit is a sense of dedication to the national interest. Its denominator is its people: their freedom to inquire; their direct responsibility for developing new and better products and processes; their cross-fertilization of ideas and sharing of knowledge.

What kind of people make up General Dynamics? Ordinary people, except that the products they make require an unusually high standard of competence, whether the individual is a production worker, a clerical specialist, a technician, or a manager. The advanced nature of many production and research programs calls for a high ratio of technically trained persons. At General Dynamics|Electronics, one out of every seven employees is technically trained. For the tactical missile operation at Convair/Pomona, there is one engineer for every three other employees. At General Atomic Division, there is one scientist, engineer or other technically trained person for every non-technical employee.

General Dynamics lives on the

frontiers of science. Its studies range from some of the oldest disciplines such as biology or metallurgy to such new ones as plasma physics and astrophysics. When necessary, the entire background of experience and knowledge from all the Corporation's technical resources can be focused to attack a single problem.

Effective anti-submarine warfare is one such problem. Militarily, the seas represent the greatest of all hiding places. The Arctic Ocean alone covers an area twice as large as the United States. As the existence of a missile-firing submarine is an immeasurable aid to the defense of this country, so the possession of similar weapons by potential enemies is a threat. To help find a counter to this threat, General Dynamics can, and does, marshal the competence of its several divisions: from Electric Boat Division, knowledge of submarine construction and warfare; from Convair and Canadair, Ltd., aerodynamic skills for air search and hydrofoils; from General Dynamics|Electronics, advanced techniques in sonar and hydro-acoustic reconnaissance.

But the ideas of men must be backed by the means with which to execute them. To provide these means, General Dynamics has invested in research and production facilities employing the most advanced equipment. A few examples for space research alone are illustrative.

High-vacuum test chambers 12 feet in diameter and 20 feet long simulate environmental extremes found in space 100 miles from the earth's surface. A working mock-

up of a three-man space station duplicates all space conditions but absence of gravity to help develop such life-support systems as waste disposal and water regeneration. Materials and components are subjected to extreme vibration and acceleration forces, at temperatures varying from 300 degrees below zero to 750 degrees above, in an ultra-high vacuum chamber capable of duplicating conditions at altitudes up to 250 miles. For space vehicle instrumentation studies, a dynamitron accelerator bombards test specimens with charged particles accelerated with energies up to three million electron volts. A hypersonic, shock-driven wind tunnel helps scientists determine heat-transfer characteristics under velocities up to 14 times the speed of sound and aerodynamic characteristics up to Mach 17. A molecular beam generator has been devised which is testing the impact effect of high-velocity molecules and ions on various target samples that represent possible space vehicle materials.



In space technology, General Dynamics already has an impressive list of accomplishments. It built this nation's first intercontinental ballistic missile. Its experience

includes both liquid and solid propellants. It is building this country's first space vehicle to use liquid hydrogen as a propellant. It is building upper stages for multi-stage rockets and payloads for them. And it is studying the propulsion systems that will replace the present chemical fuels for some missions.

The Atlas currently is the backbone of this nation's space effort. Designed as a military weapon, it was drafted for early ventures into space because it was the most powerful booster available. It won the right to spearhead the nation's space efforts because of its accuracy and reliability. Atlas is a key part of the Midas and Samos satellite programs, and of the Mercury man-in-space program, in which the first American astronaut will be propelled into an orbit around the earth.

More ambitious programs for orbital flights, lunar examination and inter-planetary missions will depend upon Atlas coupled with Centaur, a high-energy upper stage vehicle. Centaur is designed to send payloads of nearly 9,000 pounds into an orbit 300 miles above the earth, or soft-land a 1,000-pound package on the moon. It will loft large communications satellites and research satellites into orbits 22,000 miles above the earth, and send instrumented probes to other planets of the inner solar system.

Meanwhile, General Dynamics engineers and scientists are at work on other satellites, space ships and propulsion systems for the future. Code names assigned to three of these projects are

ARENTS, Apollo and Orion.

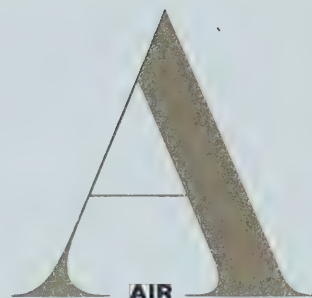
Apollo is a manned spacecraft planned to carry three men for orbital flights around the earth and for reconnaissance flights to the vicinity of the moon.

General Dynamics is cooperating in preliminary design study of the vehicle for the National Aeronautics and Space Administration. In addition to the preliminary design, the study will include requirements for construction and for propulsion, for crew protection, re-entry problems, the life-support system and guidance.

ARENTS calls for construction of three experimental satellite payloads to be launched into orbits 22,000 miles above the earth starting in 1962. They are designed to determine the effect of exposure to very high altitudes for long periods on materials, components and subsystems planned for future space programs.

A longer-range program, Project Orion, is a plan to use small, carefully controlled nuclear pulses for rocket propulsion. Still another approach involves a nuclear heat exchanger rocket, in which an enclosed nuclear reactor acts as the heat source for a propulsive gas, with nuclear energy producing high-temperature ion plasma for a propulsion drive where high acceleration is not required.

In support of these sweeping major programs, General Dynamics also is carefully going over some of the ground work that these systems will require, including the possibility of developing very small jets for controlling satellites and methods of sensing deviation from orbital path.



The transition from piston to turbine-powered aircraft will be completed by the major scheduled airlines within the next few years. After that, probably by the early Seventies, will come the next major advancement in commercial airliners—the supersonic jet transport.

General Dynamics' studies, designed to keep the company abreast of transport development, indicate that the supersonic jet passenger aircraft is technically feasible.

But it cannot be built by private capital. The magnitude of expected development costs dictates financing on a scale far beyond the capacity of any single aircraft manufacturer, or even any grouping of the major airframe manufacturers.

Studies at Convair Division indicate that the supersonic jet transport of the 1970's will be more than 200 feet long—nearly twice the length of today's jet airliners—but the span of its delta wing will be less than 100 feet, slightly under that of today's jets. It will carry about 130 passengers at cruising speeds of more than 2,000 miles an hour, yet it will be able to operate from existing major

airports. Los Angeles will be only an hour and a half from New York; Paris less than two hours.

It will be most useful on very long-range routes, such as transcontinental or trans-oceanic flights, since it rapidly loses its speed advantages over shorter distances. Even availability of supersonic transports, therefore, will leave major markets for subsonic medium- and short-range jet transports.

When the supersonic passenger airplane arrives, General Dynamics will have had an important part in its development. No other jet transport producer in the world has amassed as much experience in the design, production and flight-testing of supersonic multi-engine aircraft, or added as much to the knowledge of the art, as has General Dynamics with its 1,300-mile-an-hour B-58 Hustler bomber.



Few segments of the economy are more deeply influenced by work in the laboratories than electronics.

Both military and civilian needs call for an accelerating degree of complexity. And every increase in complexity increases the problem of reliability.

The development of the transistor

and other semi-conductor devices has provided new dimensions for building complex devices in small size with reasonable reliability. Dynamics' engineers have already set high standards for miniaturization. A missile guidance system which originally took up 1,050 cubic inches and weighed 31 pounds can be brought down to a volume of 105 cubic inches and a weight of only 4.6 pounds. A video amplifier can be reduced from 50 cubic inches and 2 pounds to less than 4 cubic inches and 4 ounces, through block packaging techniques. All components needed for one complete circuit are encapsulated into a one- or two-inch cube of plastic, to provide optimum resistance against shock, vibration and moisture.

But the demand for still higher performance requires more and more interconnected components, still smaller sizes, even greater reliability and lower costs. Scientists today are working to develop single circuit blocks which will be the equivalent of anywhere from a hundred to a thousand separate components and circuits. Units will be combined to form larger and larger combinations so that the present effectiveness of electronic equipment will be increased a thousand-fold, with reliability increased at the same time.

In the search for further improvement in block circuitry, General Dynamics is putting increased emphasis on solid-state physics.

One approach is the study of thin films. In this concept, all circuits will eventually end up as very stable micro-thin elements deposited on surfaces mainly by the process of evaporation in high

vacuum. Having virtually no thickness, such circuits can be assembled very compactly.

An equally radical approach involves the study of a phenomenon called "whisker growth," whiskers being minute bits of matter which are nearly perfect crystals. Rather than attempt to make a micro-sized device by the process of reducing the size of conventionally grown crystals, the concept here involves the use of a crystal which is micro-sized from the beginning to create fantastically small solid-state devices.

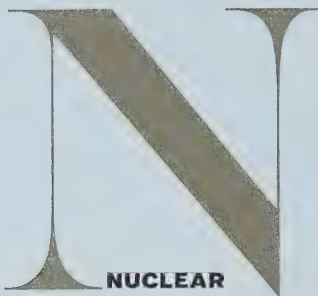
In any system, the human component is a necessary, if sometimes weak, link. General Dynamics scientists are devoting attention to the interface between human and electronic systems through biological studies, particularly on neurological systems and their basic means of communication.

Studies in communication theory have led to new insights on the problem of increasing traffic congestion on radio voice channels. For example, 18 channels of teletype material can be carried in the bandwidth required for one channel of human voice. If the bandwidth needed for speech can be compressed to an equal degree, far more voice traffic can be carried. Physicists, engineers, linguists and psychologists have pooled their efforts to find new systems of speech synthesis. By eliminating redundant sounds and transmitting, in the form of coded signals, only those needed for intelligible speech, the possibilities have been opened for new communication systems which permit a greater rate of information flow with lower error rates.

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Size of electronic equipment is reduced and reliability increased by 3-dimensional block packaging techniques as in this amplifier circuit.



Beyond the reactors and associated nuclear devices and techniques already developed, General Dynamics scientists are looking deep into tomorrow. If man can learn how to convert it to power, ordinary sea water contains enough energy to do most of his work for him.

The harnessing of this power may result from an understanding of controlled thermonuclear (fusion) reactions. Since 1957 a research program has been carried on by General Atomic Division aimed at unlocking the secret of this energy-generating process of the sun and stars.

In a fusion power system, energy would be released by the combining of two particles of heavy hydrogen under tremendously high temperatures — as much as 100 million to one billion degrees and attainable normally only in a nuclear explosion. Powerful magnetic fields appear to be a possible means of containing a plasma heated to such temperature extremes. The appealing aspect of fusion is the plentiful source of heavy hydrogen fuel (called deuterium) in nature: deuterium is present in all water.

Researchers at General Dynamics

are concerned not only with the generation of heat from nuclear and thermonuclear fuels but also with a number of advanced means of converting heat into electricity.

Scientists at General Dynamics' General Atomic Division already have turned up some clues that may have far-reaching significance in the conversion of heat directly into kilowatts, without the use of conventional rotating machinery.

Since 1957, General Dynamics' broad program of direct conversion methods has explored the use of unconventional (high temperature) semi-conductors capable of operating at more than 2,000°F, as well as other new methods of direct conversion, including the thermionic cell.

The thermionic cell consists of two plates with the inter-space containing a small amount of metal vapor, typically cesium. When made white hot by a heat source, such as that produced in a nuclear reactor, the hot plate emits electrons. These are collected on the adjacent cold plate and are tapped off as electricity. The cesium vapor is used to provide a plasma through which the current may pass more readily.

Thermionic cell converter systems appear to have great advantages for application to space vehicle power plants because of their compactness and light weight; power levels up to thousands of kilowatts may be feasible. A cesium cell thermionic converter has already produced appreciable amounts of electricity directly from the heat of a TRIGA reactor. Ultimately, direct conversion by

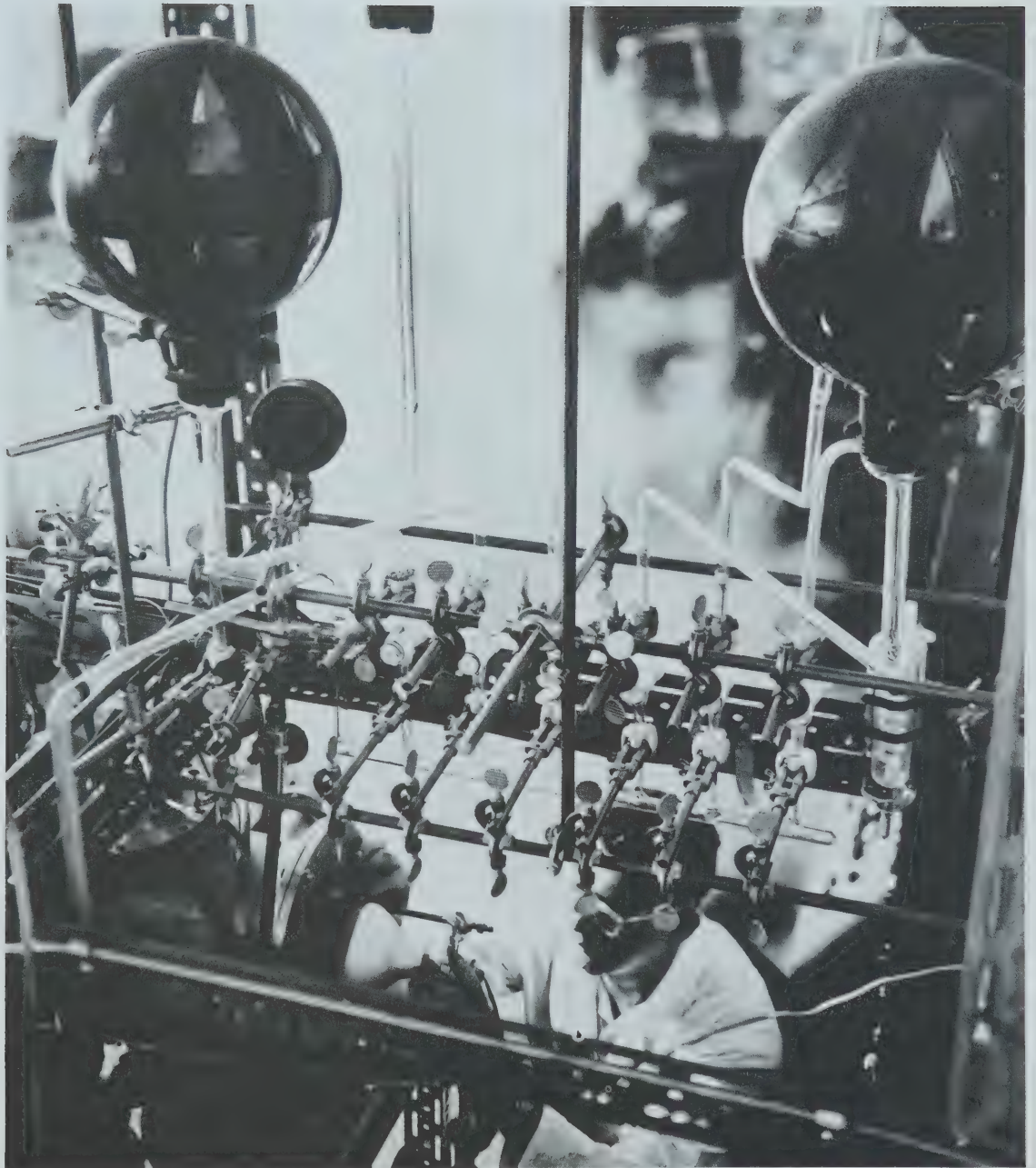
thermionic cells may be practical for marine power, and possibly for central station power in the more distant future.

General Dynamics' scientists and engineers are looking into other kinds of nuclear power applications. Among these are the use of small reactors as a remote, unattended power source, and a new concept for a nuclear-powered "ground effects" machine capable of hovering or cruising over land, sea or ice on a cushion of air.

Nuclear energy will play an important future role in the space sciences also, since it provides more power for a given weight than any other energy source known to man. Vast amounts of energy are required to propel space vehicles; the ultimate future of manned space exploration will depend on the successful development of nuclear energy as the propulsion source.

A great historian has suggested that history may not remember this century primarily for its wars, or its medical miracles, or even for the discovery of nuclear energy, but rather as that century when, for the first time, the benefits of civilization became available to all mankind.

To the achievement of that concept, General Dynamics has dedicated itself.



Atomic beam research and study of characteristics of atomic collisions is part of a broad program of nuclear energy experimental work.

OPERATING UNITS OF GENERAL DYNAMICS CORPORATION

THE PRODUCTS OF THE CORPORATION ARE LISTED INSIDE GATEFOLD

CANADAIR LIMITED

AIRCRAFT

CONVAIR

MISSILES, AIRCRAFT AND SPACE VEHICLES

ELECTRIC BOAT

SUBMARINES

ELECTRO DYNAMIC

ELECTRIC MOTORS AND GENERATORS

GENERAL AIRCRAFT AND LEASING

SALE AND LEASING OF AIRCRAFT

GENERAL ATOMIC

NUCLEAR ENERGY

GENERAL DYNAMICS | ELECTRONICS

ELECTRONIC AND COMMUNICATIONS
EQUIPMENT

LIQUID CARBONIC

COMPRESSED GASES

MATERIAL SERVICE

BUILDING MATERIALS, COAL AND LIME

PRODUCTS OF GENERAL DYNAMICS CORPORATION

AIRCRAFT:

F-106 supersonic all-weather jet interceptor
B-58 Mach 2 four-engine jet bomber
Convair 880 medium-range commercial jet transport
Convair 990 medium-to-long-range commercial jet transport
NX-2 nuclear-powered bomber (in design stage)
CL-28 long-range submarine hunter-killer
Canadair Forty Four four-engine swing-tail turboprop cargo transport
CF-104 supersonic jet strike/reconnaissance aircraft
Canadair 540 twin-engine turboprop transport
CL-41 primary and basic jet trainer

MISSILES AND SPACE VEHICLES:

ARENTS environmental test satellites
Atlas intercontinental ballistic missile and space booster (for USAF and NASA)
Atlas-Centaur high-energy space craft
Black Brandt II high altitude research rocket
Tartar surface-to-air guided missile (Navy)
Terrier surface-to-air guided missile (Navy)
Redeye shoulder-fired missile system (Army)
Mauler mobile battlefield air defense missile system (Army)

NUCLEAR SUBMARINES:

COMMISSIONED:

SS(N) Nautilus
SS(N) Seawolf
SS(N) Skate
SS(N) Skipjack
SSR(N) Triton
SS(N) Scorpion
SSB(N) George Washington (Polaris-firing)
SSB(N) Patrick Henry (Polaris-firing)
SS(N) Tullibee

UNDER CONSTRUCTION:

SSB(N) Ethan Allen (Polaris-firing)
SSB(N) Thomas Edison (Polaris-firing)
Four Lafayette-class Polaris missile submarines
Three Thresher-class attack submarines

DEFENSE ELECTRONICS:

Airborne air navigation systems
Airborne computers
Antennas and radomes
Anti-submarine-warfare equipment
Automatic check-out equipment
Azusa missile-tracking systems
Battle announcing systems
Electronic countermeasures equipment
Electronic switching telephone systems
Infrared instrumentation
Military surveillance and reconnaissance systems
Mobile radio transmitters and receivers
Performance monitors
Radar equipment, airborne, ground, and shipboard
SCATE automatic test equipment
Single sideband communication equipment
Strobe-light missile-tracking systems
Training and simulation devices

COMMERCIAL ELECTRONICS:

Aircraft data-link systems
Automatic air-traffic control systems
Automatic test equipment
Automobile radios and loudspeakers
Beacon monitoring and control equipment
Burst transmission systems
Cathode ray tubes
Charactron shaped beam tubes
Computer readout display and recording equipment
Data transceivers
Electronic printers
Facsimile transmission systems
Intercommunication systems for industry and schools
Mail sorters and coders
Nuclear reactor instrumentation and controls
Pagemaster selective wireless paging system
Public address systems
Simulators and training devices
Special-purpose data processing and computer systems
Stereophonic and high-fidelity consoles and components

NUCLEAR PRODUCTS:

High-temperature, graphite - moderated gas-cooled reactors for electric power generation
Beryllium oxide-moderated gas-cooled reactors for ship propulsion and electric power
Nuclear irradiation services
TRIGA Mark I and Mark II reactors for training, research and isotope production
TRIGA Mark F reactors for high power pulsed operation
Major research projects also include:
Auxiliary power units for spacecraft
Direct conversion of heat into electricity
Controlled thermonuclear (fusion) reactions
Large nuclear pulse propulsion vehicles
Radiation shielding of combat vehicles

TELECOMMUNICATIONS:

Electronic and electromechanical switching systems
Dial and manual switchboards
Manual, dial and electronic telephone instruments
Telephone components and test equipment
Toll ticketing apparatus
Carrier and multiplex equipment

BUILDING MATERIALS:

Redi-Mix concrete
Sand, gravel and crushed stone
Cen-Vi-Ro concrete pipe
Lin Tee prestressed concrete beam
Dynacore prestressed concrete cored slab
Materialite lightweight concrete aggregate
Curtain walls for multi-story construction

COAL: (Sold under the following trademarks)

Crown
Orient
Freeman
Orient Supertherm Stoker Coal
Orient Airflow Stoker Coal
Freeman Bantam Stoker Coal
Freeman Freeburn Stoker Coal

COMPRESSED GASES:

Carbon dioxide, solid, liquefied and gaseous
Hydrogen
Oxygen
Acetylene
Nitrogen
Argon
Helium
Propane
Nitrous oxide
Ethylene
Cyclopropane
Mixtures of above gases for special industrial or medical applications.

INDUSTRIAL EQUIPMENT AND MATERIALS:

Abdominal decompression chambers
Anesthesia equipment
Autotrack jet-engine vibration analyzer
Azimuth and elevation drives for "Big Dish" 600-foot radio telescope
Ball valves
Cargo handling equipment
Dynapak high-energy machine tools
Dynawire welding wire
Electric motors and generator sets
Extracts and flavors
Gas storage equipment
High-frequency power supplies
Hospital piping systems
Hydraulic leak meters
HyGe shock simulation machines
Inhalation therapy equipment
Lime products
Liquid/gas detectors
Masco petroleum products (as distributors)
Mineral feeds
Nuclear-radiation detectors
RAT tracked vehicles
Refractory materials
Shock overload indicators
Vaneaxial fans
Vibraforce analyzer
Wind tunnel actuator and controls
Welding and cutting equipment

Note: This is a partial list. Single items labeled "equipment" or "systems" stand for a number of individual products. Military research and development contracts are not included.

